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ABSTRACT

The purpose of this study was to ascertain the feasibility of incorporating certain protective concepts into selected systems-constructed schools. These concepts were to be incorporated at a minimal cost increase, with minimal sacrifice of amenities, and with no detrimental effect on facility configuration. The environmental hazards taken into consideration were earthquakes, tornadoes, hurricanes, and noise. The five schools selected for analysis are currently in use. The design changes are offered as suggestions that might be incorporated into future designs in order to better protect the inhabitants of the facility. Photographs may reproduce poorly. (Author/MLF)

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November 1973

Environmental Hazards & Systems Schools

U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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EA 006 574

A report prepared by
The School Planning Laboratory
University of Tennessee

in cooperation with
United States Office of Education and
the Defense Civil Preparedness Agency

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John E. Davis
Director
Defense
Civil Preparedness
Agency

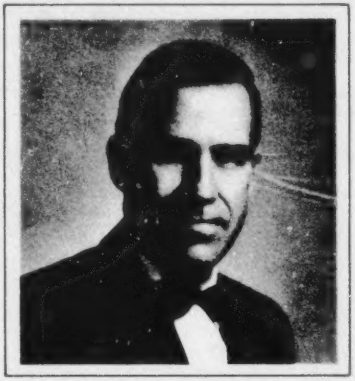
Recently, the President authorized the Defense Civil Preparedness Agency to broaden its preparedness objective to include peacetime-disaster readiness as well as the kind of preparedness needed in a nuclear crisis.

As a result, we now concentrate on helping the community build up its emergency plans, facilities, and leadership to cope with the immediate threats to public safety—hurricanes, tornadoes, floods, — in the knowledge that these capabilities are the key to coping with a nuclear crisis as well.

When we add school buildings to such a system, we do it with the knowledge that they are strategically located in every neighborhood of the country and have traditionally been public rallying points. They are also the daytime habitats of an important major segment of the population—our school children.

This booklet shows how a recently developed school construction type—the industrial-construction school—can protect in time of emergency.

William W. Chase
Project Director
National Center
For Educational
Technology



Systems construction in the United States is gaining in popularity due to its possibilities for shorter construction time and concomitant economic savings. Systems school construction also provides for fluid teaching spaces which meet today's changing educational needs.

The schoolhouse has traditionally been utilized as a place of refuge in times of emergency; in light of today's population concentration in and around urban centers, the school assumes an even more important protective role.

With the increased popularity and utilization of systems construction, an investigation of this nature becomes of prime importance.

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Robert Berne, AIA
Chief Architect
Defense
Civil Preparedness
Agency

Industrialized construction—where building units are prefabricated in remote plants and shipped to the site for erection—has been used successfully in Europe for many years. Recently, the system has been introduced to the United States, and it has already been applied to school construction in a number of areas that have widely varying environments.

How industrialized-building schools protect their occupants against environmental hazards of all types is an important architectural consideration. The School Planning Laboratory, in this study, has investigated ways in which protection has been accomplished, with a view towards highlighting the need to consider it, in this popular building type.

School boards, and their architects, considering the industrialized building to meet facility needs will find much valuable information in this report to guide them in their expansion programs.

Dr. Charles E. Trotter, Jr.
Director, School Planning Laboratory
Project Director
The University of Tennessee

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Arthur Dexter
Principal Investigator

About the Study

Educators and architects have given considerable attention to systems school construction as evidenced by the growing number of buildings employing standardized components to provide rapidly and economically for meeting the needs of schools.

Educators have welcomed systems concepts for their flexibility and ability to accommodate today's educational requirements.

Not all problems may be solved by this construction technique. For example, by definition, there is very little means to provide protection from either natural or nuclear disasters.

This study was initiated to determine if the systems approach to school construction can provide adequate protection for hurricanes, tornadoes, earthquakes, and nuclear disasters without noticeably increasing the cost of construction. The School Planning Laboratory was pleased to have been provided the opportunity to explore this problem with the U.S. Office of Education and with the Defense Civil Preparedness Agency.

This project was undertaken in order to explore the protection against certain selected environmental hazards afforded by schools constructed through a systems method. Those hazards which were taken into consideration were earthquakes, tornadoes, hurricanes, and noise.

The selected schools are currently presenting viable, meaningful programs of instruction, and the suggested changes in design will in no way affect programs or the aesthetic appearance of the buildings.

The suggested design changes are in no way to be construed as an indictment of the systems approach, but a suggestion which might be incorporated into future design in order to better protect the inhabitants of the facility.

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What is Systems?

Systems is an approach to school facility construction that will contribute to improved buildings that can be constructed quickly and economically.

In essence, systems construction utilizes the efficiency of modern industrial mass production of basic components that make up the school building. (It also allows the manufacturers to introduce precise educational requirements much earlier than would be possible otherwise.)

Systems construction simplified the traditional building process by a duplication of the basic building components, with flexibility for future change as a characteristic.

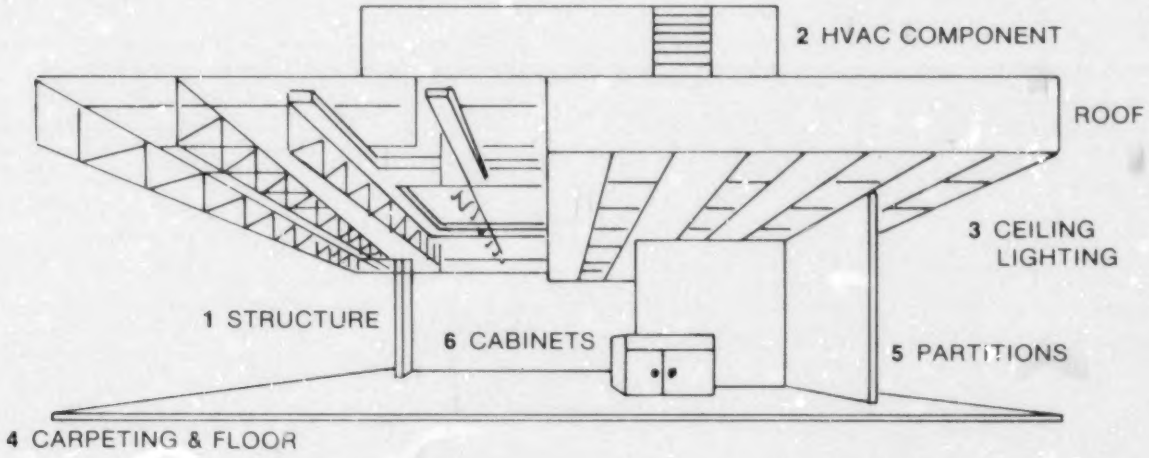
School construction systems development involves three basic steps:

(1) the user must be definitive in his physical requirements in terms of activities that will occur in the schools,

(2) these user requirements must be translated into a set of performance specifications, and

(3) industry must meet those specifications in terms of the hardware or subsystems components.

In implementing these three steps, two types of building systems are possible. The closed system (SCSD is an example) uses a single set of basic building components which have been specifically designed to integrate exclusively with one another. The open system (Florida's SSP, for example) allows for the interchange of various building components from different manufacturers. In the closed system, for example, the HVAC will only be compatible with one structural subsystem; in an open system it will be compatible with most or all of the subsystems bid.



Designing and programming involves nine basic steps:

(1) Contacting the architect and signing contract,

(2) Developing an educational program,

(3) Determining building programming and project scheduling,

(4) Obtaining approvals of design,

(5) Preparing bid documents for subsystems,

(6) Receiving bids on subsystems,

(7) Preparing working drawings and specifications,

(8) Letting contracts, and

(9) Inspecting and supervising construction.

A possible exception to the above would be a utilization of two-stage bidding. In general, bids are taken following the completion of the working drawings and related contract documents. Two stage bidding follows the same procedure but adds earlier bidding for key components known as "pre-bidding."

Pre-bidding, therefore, is taking competitive bids which are based on preliminary design and abridged specifications, oftentimes performance oriented, for building systems and other components before the working drawings have been developed.

In the Florida SSP, the compatibility of the facility components is visibly demonstrated in the sketch above. Construction of the systems school begins with the structure (1) erected in only days instead of weeks or months. Next, the roof, environmental controls and distribution (2) are installed, followed by the lighting/ceiling (3) system unit. Other components go into the building simultaneously, such as the exterior walls of whatever material the architect has chosen, and the electrical/plumbing units. Carpeting (4) is laid throughout the building before the installation of the demountable and operable partitions (5). Cabinetry (6) and special equipment complete the school building.

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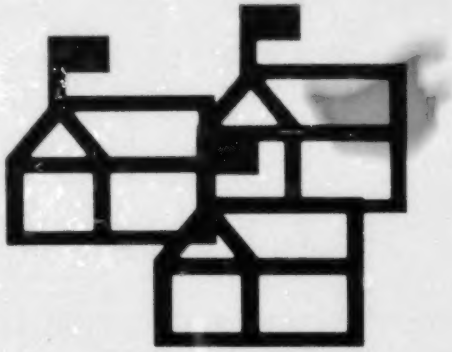

Facility Selection

The focus of this project was to ascertain the feasibility of incorporating certain environmental protective concepts into selected systems-constructed schools. These conceots were to be incorporated at a minimal cost increase, with minimal sacrifice of amenities, and with no detrimental effect on facility configuration. Therefore, the design concepts which are incorporated in this document differ from school to school.

Facility design, even though all are systems schools, displayed a variance as each of the various geographical locations was taken into consideration. All are currently in use and offer educational programs which present a viable, meaningful, and educationally sound opportunity to those in attendance.

School selection was based upon a prior determination of that area of the United States in which the highest incidence of occurrence for each hazard was recorded. A second determining factor in selection was that none of the facilities was so unusual in design that a counterpart could not be located in another area of the country.

All of the facilities are located in suburban areas where the majority of our population spends the greater percentage of its time. Also taken into consideration was the fact that the urban centers with their large and exceptionally well-built buildings are provided with a number of shelters from environmental and manmade hazards.

The environmental hazards taken into consideration were earthquakes, tornadoes, hurricanes, and noise. The educational facilities of Broward County, Florida, were utilized for the segment on protection from hurricanes, those in and around San Jose, California, for added protection from earthquakes, Chantilly High School in Fairfax County, Virginia, for protection from unwanted sounds and for the incorporation of protective concepts from tornadoes. It was found that while incorporating an increased degree of protection for one hazard, there was a concomitant increase in protection from the others, both nuclear and environmental.

The configuration of each of the schools was arrived at after due consideration had been given to the sacrificing of educational goals, aims and objectives, structural amenity and the normally right budgetary allocation. It would be a simple task to provide protection without the above considerations.

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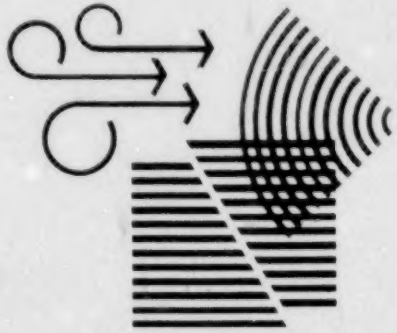

Hazards

Noise

Cleaning up America's polluted air and water is a job for all citizens, industry, and government at all levels. An aroused America is moving with determination on various fronts to defeat these debilitating pollutants of our natural resources.

What about noise and its disastrously cumulative effects?

Noise has been functionally defined as unwanted sound. This unwanted sound, or noise, can range from a level at which it is merely disturbing to levels at which exposure can result in violent psychological or physiological reactions. It is measured in units called decibels.

Victor Gruen, a notable architect and urban planner, said, "Noise is like smog in that they are both slow agents of death." This view is shared by Dr. Vern O. Knodsen, professor of physics and chancellor emeritus of the University of California. He is of the belief that if noise continues to grow at the present rate, it could be fatal for many humans. Doctors believe that noise, through the stimulation of the reaction of fear or rage, may cause high blood pressure. Dr. Giovanni Streneo of Italy found that constrictions of the blood vessels in fingers and eyes and dilation of those in the brain can be inflicted by noise. He also found that noise endangers the heart by directly altering the rhythm of its beat.

Noise in and around our cities has become one of the end products of man's constant drive toward things bigger, better, and faster than before. The emergence of the supersonic transport (SST), with the ensuing controversy over the noise levels it would produce, is a prime example.

The Federal Aviation Administration recently reported that, at the present rate of growth, O'Hare International Airport in Chicago will increase the area seriously affected by noise from 72 square miles in 1965 to 123 square miles by 1975. The population affected will increase from 236,000 to 432,000.

In New York City, John F. Kennedy International Airport causes similar noise problems. Kennedy air traffic produces damaging, disturbing noise that affects 23 square miles, 35,000 dwelling units, over 100,000 residents, and 22 schools.

It was determined in another study that, in a senior high school located one mile south of Los Angeles International Airport, the exterior noise level would be at 85.0 db, but that through school partitioning and room arrangement they were able to take advantage of both distance and effective barrier usage to assist in sound level reduction. The exterior walls and slabs were all concrete and no windows were in

line with the direct propagation of the primary sound sources. The use of double glazing aided in the reduction of sound transmission.

It has been determined that a prolonged exposure to sound in the 85 db range could result in a hearing loss. The rapid expansion of jet transport operations, as well as the spiralling popularity of the small commercial and private jet aircraft, has led to intensified noise problems. Today's cities and those areas which surround modern airports reach this potentially damaging level in a number of ways. In order to help alleviate this problem adjacent to airports, the Federal Aviation Agency has established regulations which restrict helicopter, prop, and jet noise.

It is imperative in light of today's knowledge concerning the deleterious effects of unwanted sound (noise) that we recognize its seriousness and not only initiate legal control but also acoustically treat our buildings.

Hurricanes

The word "hurricane" undoubtedly conjures up the most pervasive fear in man's mind of any of the variety of storms he must endure. The hurricane brings devastation by wind, flooding, and the storm surge.

There is still no exact understanding of the mechanism which triggers hurricane generation, but conditions needed to produce hurricane circulation, as well as the relationships between the actual hurricane and the surrounding atmospheric processes, are understood. Hurricanes are tropical cyclones which are formed in the atmosphere over warm ocean areas. In order for a storm to be technically classified as a hurricane, its winds must reach a velocity of at least 74 miles per hour. These winds blow in a large spiral around the "eye" which is the comparatively calm center area. Hurricane circulation is counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. The far-ranging winds of hurricanes (up to 100 miles) are often responsible for the spawning of tornadoes.

In a hurricane, winds move toward the low pressure area in the warm and somewhat placid core. There the converging currents are drawn upward. This spiral action is marked by thick cloud walls which curl inward toward the storm center and release heavy precipitation and enormous quantities of heat energy.

At the center of the hurricane is the core, or "eye," which is unique to this storm. No other atmospheric phenomenon has this virtually calm core. An average eye diameter is about 14 miles, and wind velocities diminish inwardly to about 15 miles per hour.

However, each hurricane is a storm unto itself and therefore individual storm characteristics may or may not conform to the above description.

In general, hurricane winds will not usually cause building damage until the wind velocity exceeds 100 miles per hour; nevertheless, buildings which are not structurally resilient will suffer excessive amount of damage with a velocity increase of 25-50 miles per hour. Architects, then, have a mandate to design buildings capable of withstanding high wind loads.

Earthquakes

The earthquake, of all the natural disasters which this country faces, has the potential capability of inflicting the greatest loss of life and property damage. Our planet is subjected to approximately one million earthquakes a year, and thousands of small earthquakes occur in the United States.

Our planet is not "solid" as thought by some but actually in a state of mercurial vacillation. It is acted upon by the periodic forces of the solar system which produce stresses and movement of the earth's surface. Recent evidence indicates that the material from the upper mantle is welling up along the mid-Atlantic ridge and precipitating the movement of large areas of the earth's surface called "plates." These plates are believed to interact in any one of these ways: spreading where new crust is formed, subduction (one plate plunging under another), or fault action (two plates rubbing).

The widely known earthquake belts are outlines of large plates and give a measure of the amount and kind of movement which occur at the interface of the blades defined. As these bodies move relative to one another, stresses form and accumulate until a fracture or abrupt slippage occurs. An earthquake, then, is the resultant release of stress usually occurring within a few kilometers of the earth's crust.

The relatively small part of the crust at which the stresses are relieved by movement is the focus of an earthquake. Earthquake severity is dependent upon the amount of mechanical energy released at the focus, and the structural properties of the area at or near the surface of the earth at the point of observation.

An earthquake's magnitude is generally reported as having been a 7.5 or similar number with a range of 0-8.9; however, there is no lower limit or upper limit. It is estimated that the energy released by a magnitude 8.5 earthquake on the Richter scale is equivalent to 12,000 times the energy released by the Hiroshima nuclear bomb.

The greatest proportion of seismic activity in the United States occurs along the far western border of our country. California and Alaska record the highest number, with extensive activity in Washington, Oregon, and Nevada. However, no area in the world is free from the ramifications of this destructive force.

Due to increasing population density, particularly in the area of known faults, the possibility of a major catastrophe daily becomes less remote.

The architect must not only deal with building-code defined force but must concern himself with altered foundation support. An earthquake-proof structure cannot be guaranteed; nevertheless, the use of codes, utilization of the most detrimental loading conditions as criteria, and the use of unitized frame construction with moment-resistant connections is essential if the risk factor is to be significantly diminished.

Tornadoes

Of all the various types of weather phenomena which we experience in the United States, the tornado is the most abruptly violent. No other weather disaster strikes with such suddenness, making large-scale evacuation almost an impossibility.

Tornadoes are local atmospheric storms of short duration formed of winds rotating at very high speeds, usually in a counter-clockwise direction. A tornado is visible as a whirlpool-like column of winds swirling about a hollow cavity. In this center cavity, a partial vacuum is formed through centrifugal force. As condensation occurs around the vortex, a pale cloud appears which is the familiar and extremely frightening tornado funnel. As this storm travels along the ground, the outer ring of rotating winds becomes dark with dust and debris, thus giving the storm an even more ominous appearance.

While tornadoes may be theoretically formed either through thermal or mechanical effect, it is probable that tornadoes are produced by the concomitant interaction of both. Tornadoes are ordinarily associated with thunderstorms and form along the path of the storm, travel for a short distance, and then dissipate. Their forward speed may range from almost 0 to 70 miles per hour.

On the average, tornado paths are about one eighth of a mile wide and only rarely over 10 miles long. However, several tornadoes have been up to a mile wide and 300 miles in length.

The destructiveness of a tornado is the ultimate result of a combination of the burgeoning rotary winds and the partial vacuum in the vortex. The wind causes exterior devastation, and the ensuing pressure reduction in the eye can cause explosive over-pressures inside the building.

All 50 states have at one time experienced a tornado, but the Midwest and the Southeast are the most patently vulnerable areas.

Tornado protection must be incorporated early in the design stage. NOAA recommends that shelter should be sought from tornadoes in a tornado cellar, underground excavation, or a steel-framed or reinforced concrete structure of substantial construction.

It was the original intent of this document to include examples of the incorporation of protection from tornadoes into systems buildings. Our study, however, pointed out the impossibility of such incorporation in a systems building and remain within our parameters of cost feasibility and systems construction.

Due to the great mass necessitated to resist the forces of tornadoes, (approximately 7 inches of concrete folded plate construction in one instance for the roof), it then becomes necessary to "beef up" the supporting structural system or completely redesign the area to receive the protection needed.

Fallout protection

As in obtaining protection from tornadoes, the method for gaining fallout protection is through the utilization of mass. Limited by the parameters of cost and the utilizaton of systems construction it is, at this time, impossible to incorporate fallout protection into systems schools

However, work presently being done with prestressed concrete systems may develop a solution to this problem.

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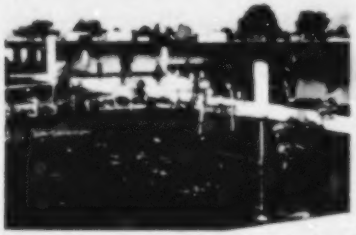
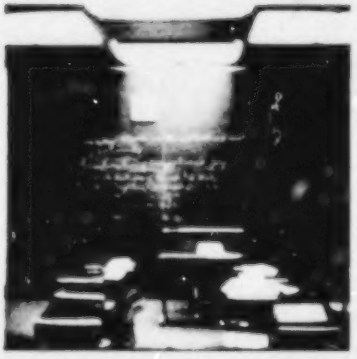
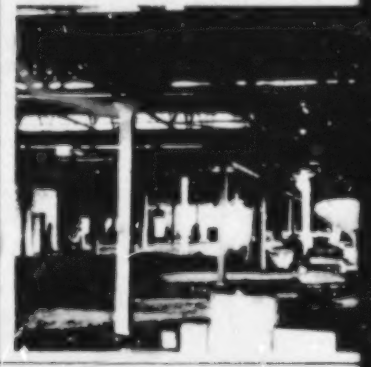
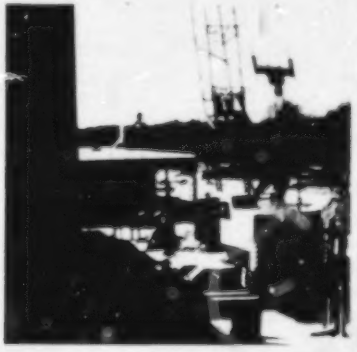
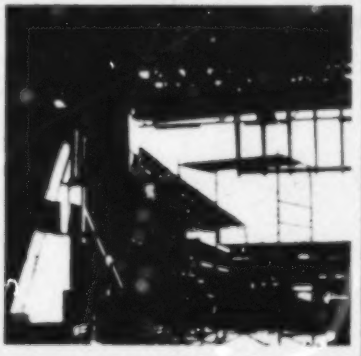
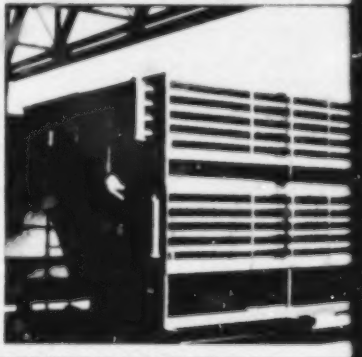
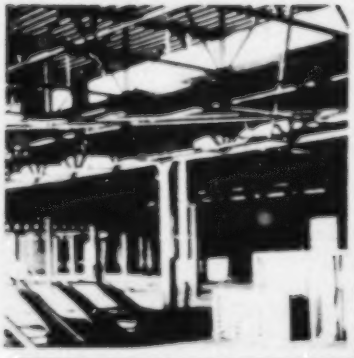
Facilities







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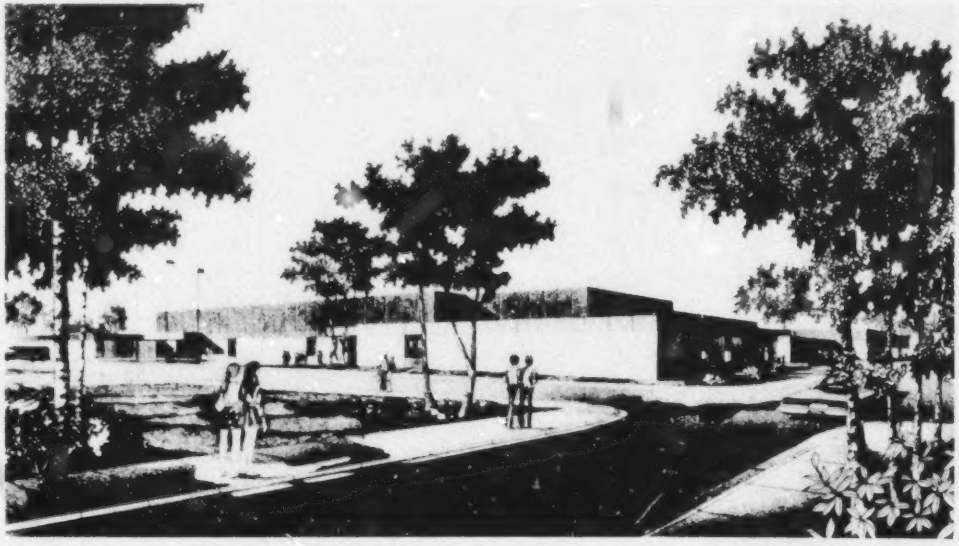


Chantilly High School

The Hazard—Noise
The School—Chantilly High School, Fairfax County, Virginia
The Architect—Berry, Rio & Associates, AIA

About the School

Chantilly High School is designed for 2,500 full time students and 300 part time vocational students. The construction was fast tracked with 13 separate contracts let. The school is organized with provision for a school within a school. The four humanities halls will accommodate 625 students each. The design allows for change in organizational structure, freedom from restrictive physical barriers, and provides interchangeable multi-use spaces.

The structure is based on a 5' x 5' grid with floor bays of 30' x 30' and roof bays generally 30' x 60'. The exterior skin is precast concrete and sandwiched insulation. The roof is 2½" poured gypsum over 2" insulating formboard. Windows are minimal and glazed with sound insulating glass. Exterior doors open into circulation areas. All duct work has been acoustically treated with attenuators and offsets.

The interior of the building will also receive full acoustical treatment with carpeted floors, acoustical tile ceilings, and wall treatment where necessitated.

Design Criteria

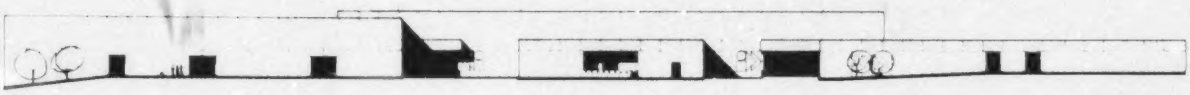
Outside Noise Level =	90-93 dB
Interior Noise Level =	50-55 dB
Walls-Roof System	
Filter out =	40-45 dB
stc =	41 + dB

Grades	Pupil Capacity	Area
9-12	2,800	338,266 sq. ft.
Construction Cost		**Per Sq. Ft. Cost**
$7,115,620		$21.03

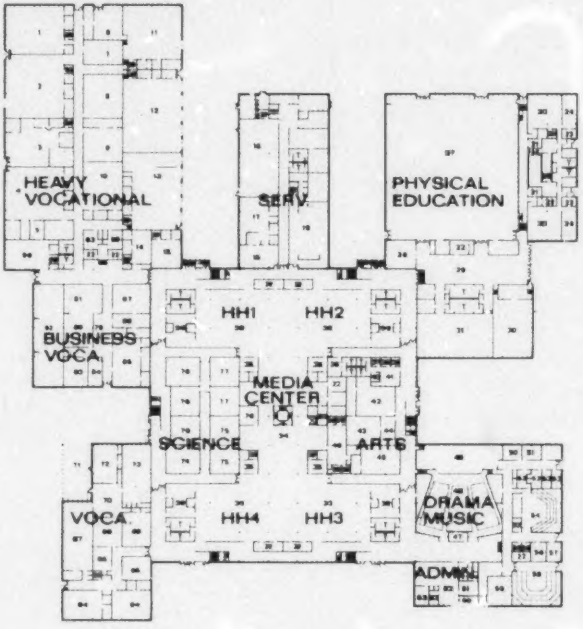
Additional cost for acoustical treatment over conventional building = None

Longitudinal Section

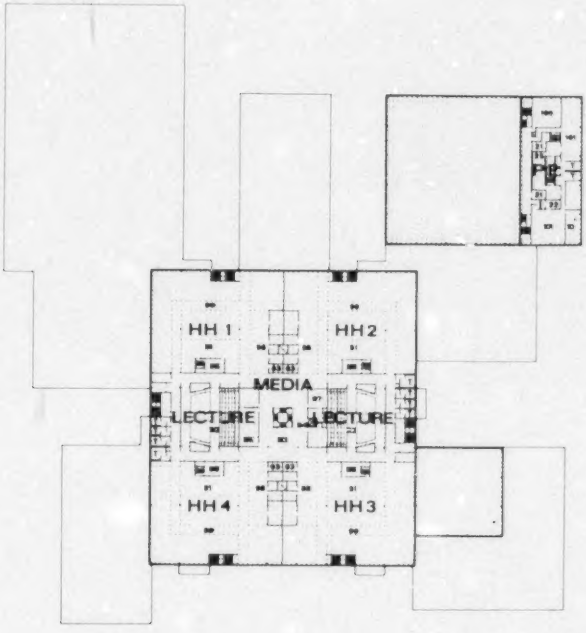
Transverse Section



East Elevation



First Floor Plan



Second Floor Plan

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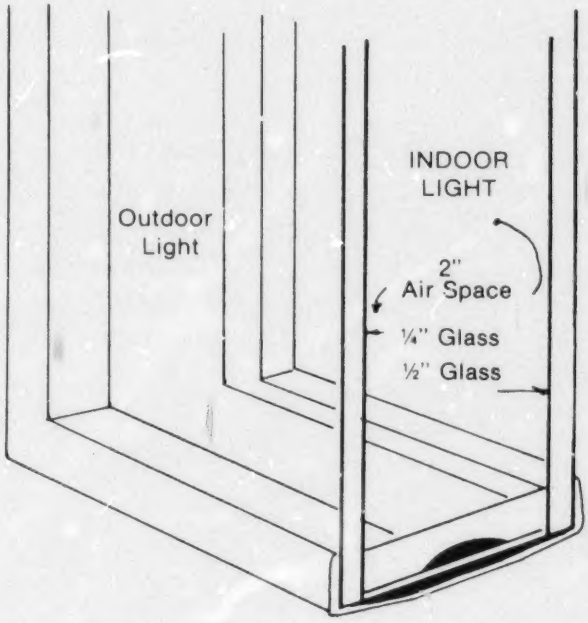
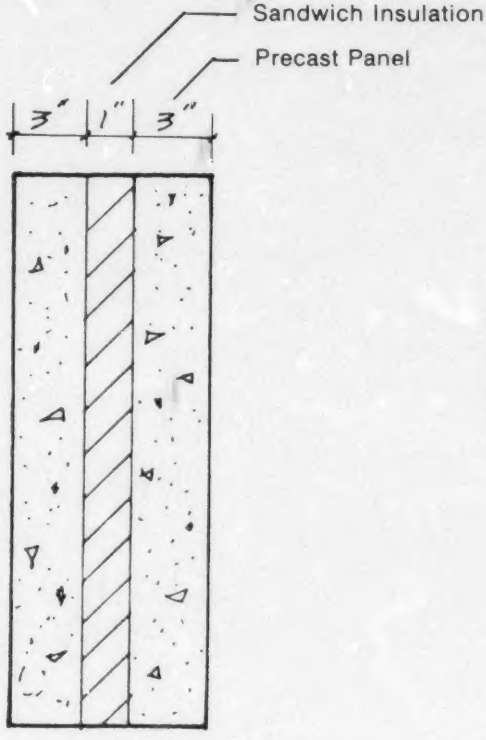
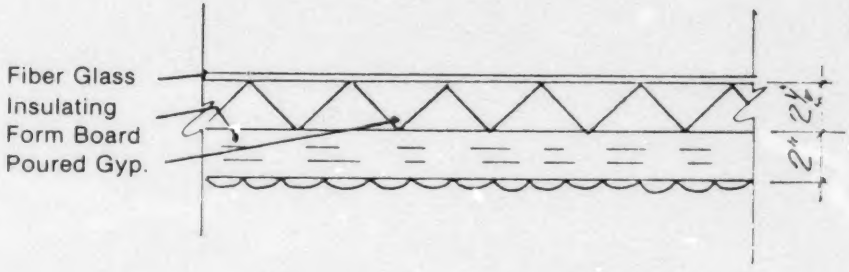


Typical Section-2" Air Space—Acoustical Window



Roof System



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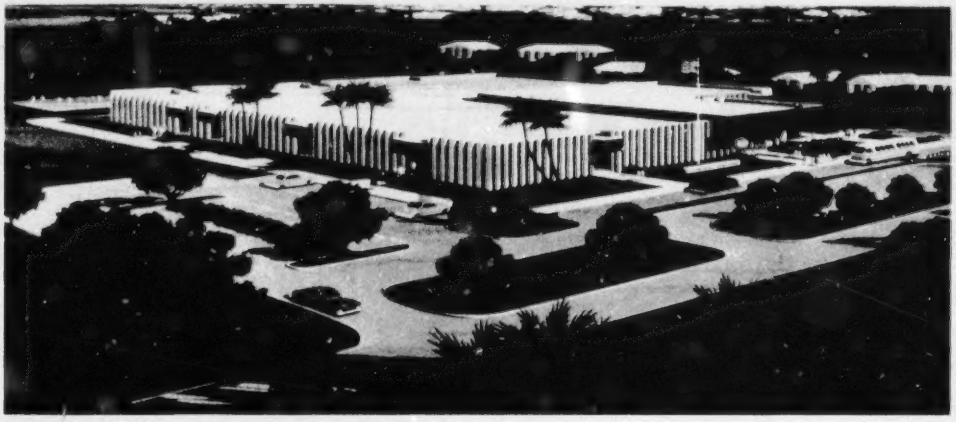

Pasadena Lakes Elementary School

The Hazard—Hurricanes
The School—Pasadena Lakes Elementary School, Broward County, Florida
The Architect--Benham, Blair and Associates of Florida

About the School:

Pasadena Lakes Elementary School, located in Broward County, Florida, is a K-6 facility with an open space concept. There are several academic divisions within the school, namely: a kindergarten area; an open 1-3 academic area; an open 4-6 academic area; a media center which is available to all other areas; an art area; and a combination cafeteria-auditorium.

The structure is a one-story steel frame and trusses supported on reinforced concrete spread footings, double "T" precast concrete exterior wall panels furred on the inside with metal studs and gypsum board. The roof system is metal decking with 20 year built-up roofing over lightweight concrete fill.

Grades	Pupil Capacity	Area
K-6	650	47,000 sq. ft.
Construction Cost		**Per Sq. Ft. Cost**
$999,995.00		$23.44

Additional cost for the inclusion of hurricane protection = 3% of contract cost.

Pasadena Floor Plan

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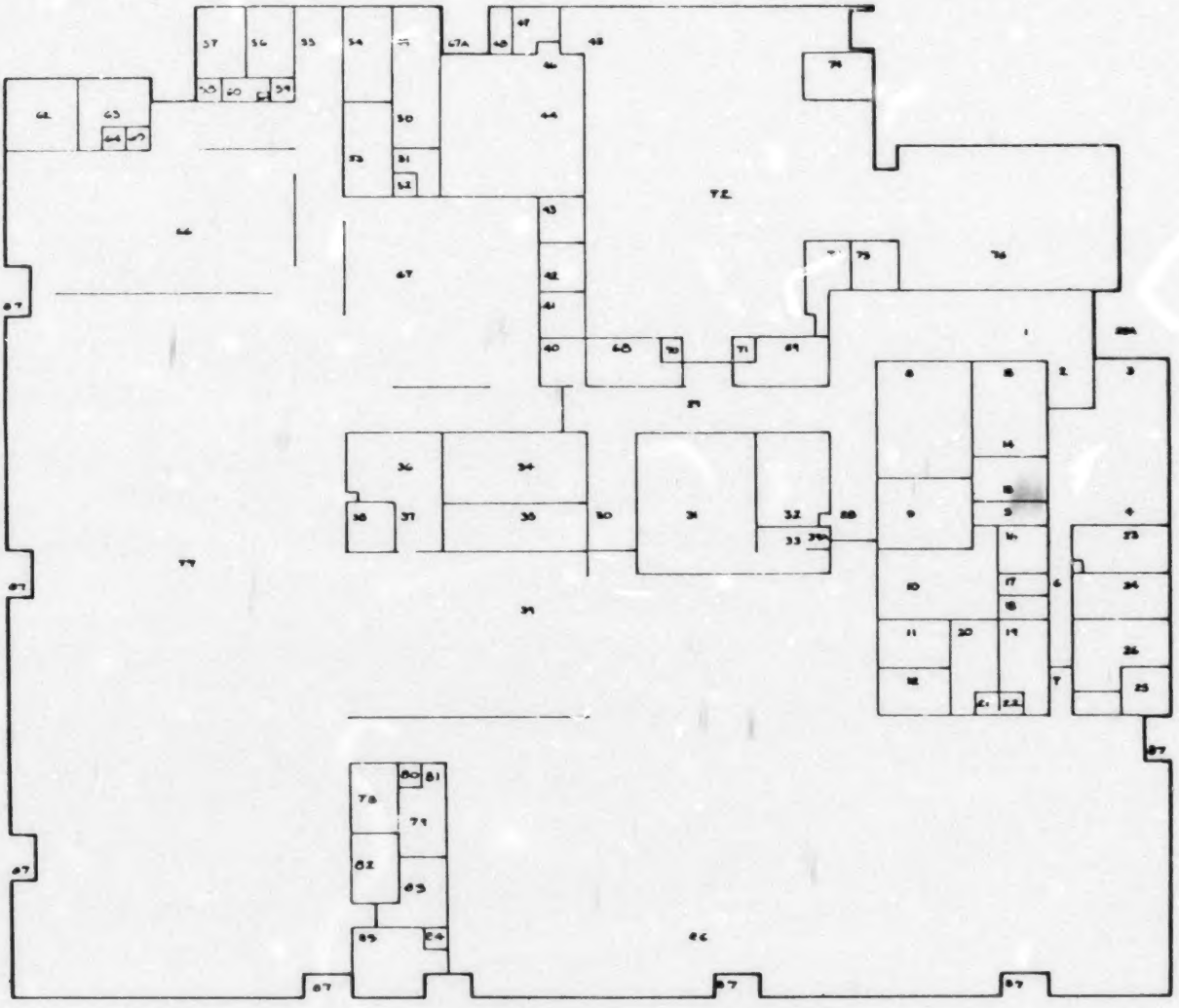

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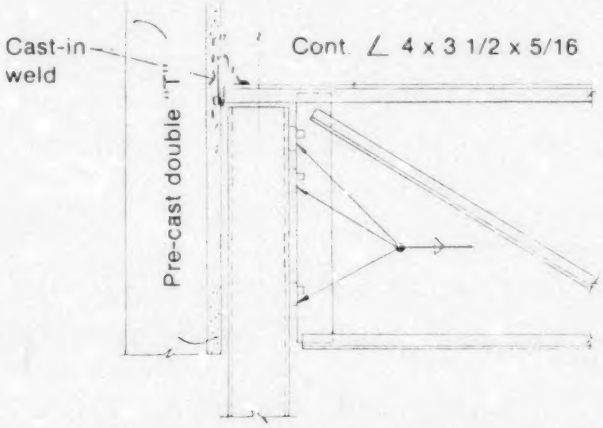
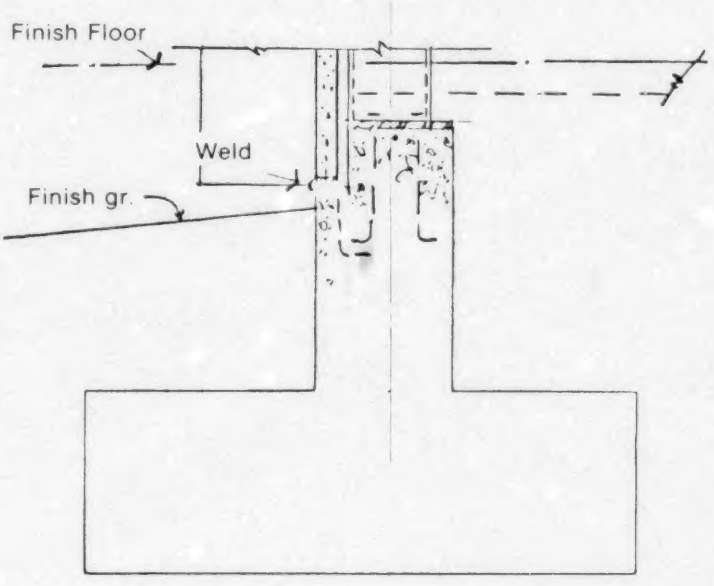
Construction Details

illustrated below are several methods utilized in tieing in the roof system and a detail of a possible footing design





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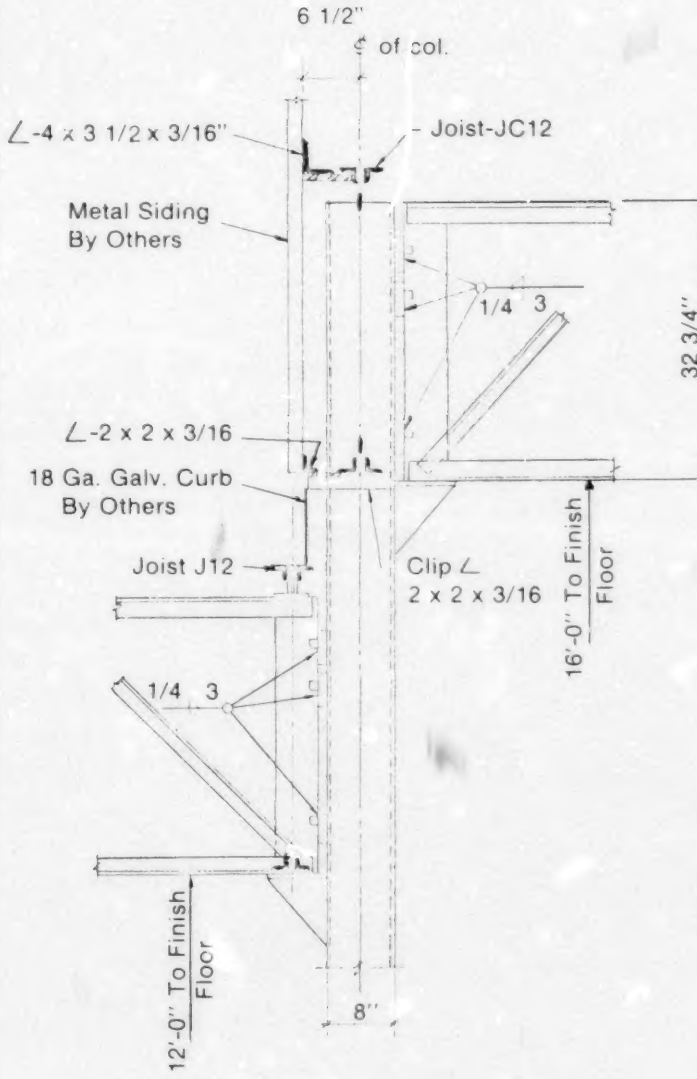

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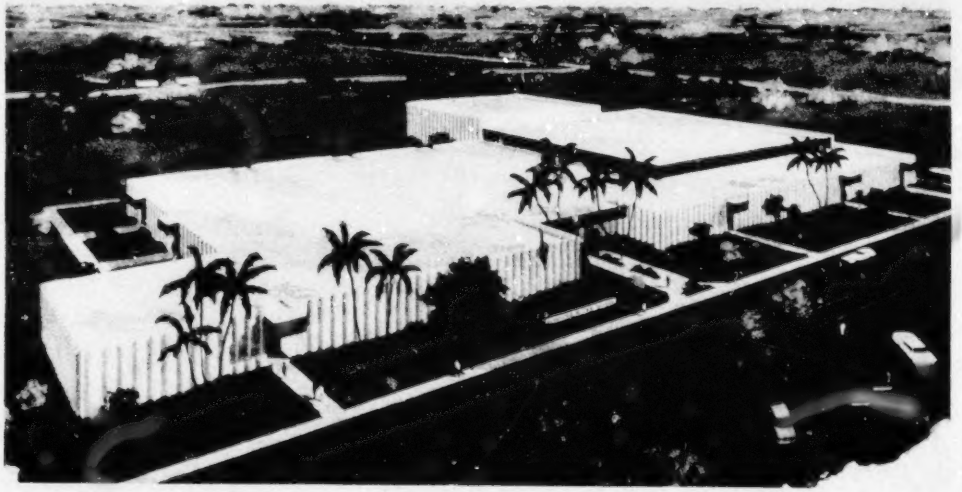


Seminole Middle School

The Hazard—Hurricanes
The School—Seminole Middle School, Broward County, Florida
The Architect—Benham-Blair & Associates of Florida, Inc.

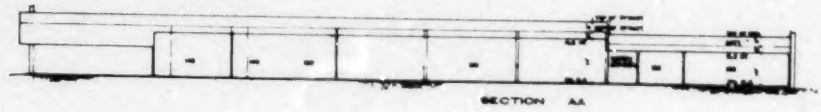
About the School:

Seminole Middle School was designed to house 1250 students on a 16.5 acre site. The facility is divided into 6 instructional areas: (1) mathematics, social studies, language arts, and science; (2) unified arts, home economics, art, visual communications, American industry; (3) music; (4) physical education; (5) media center; (6) food service (instructional cafetorium) and supportive services areas.

The facility is a one-story steel frame and trusses supported on reinforced concrete spread footings, double "T" precast concrete exterior wall panels furred on the inside with metal studs and gypsum board. The roof system is metal decking with 20 year built-up roofing over lightweight concrete fill.

Grades	Pupil Capacity	Area
K-6	1250	103,000 sq. Ft.
Construction Cost		**Per Sq. Ft. Cost**
$2,192,650		$21.30

Additional cost for the inclusion of hurricane protection = 3% of contract cost.



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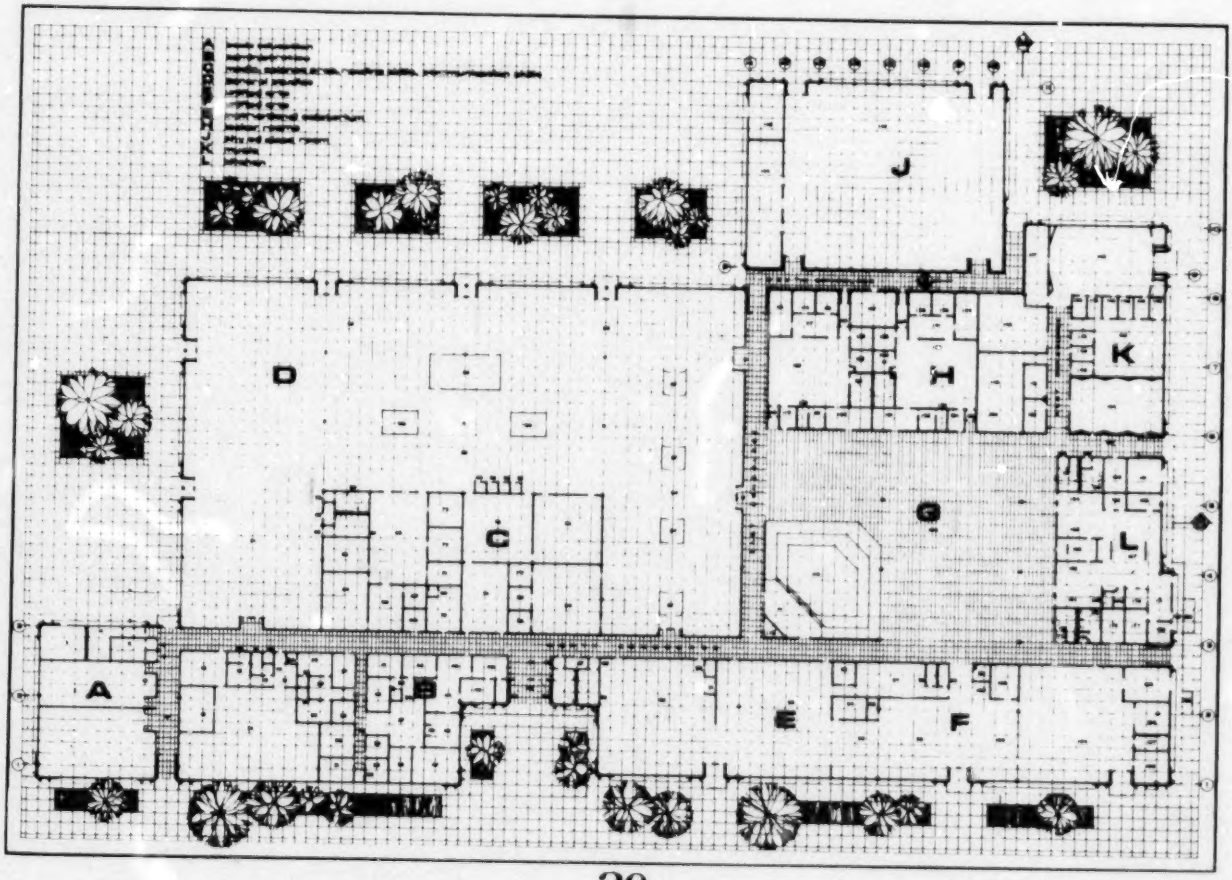
Seminole Floor Plan



Wind Pressure Diagram

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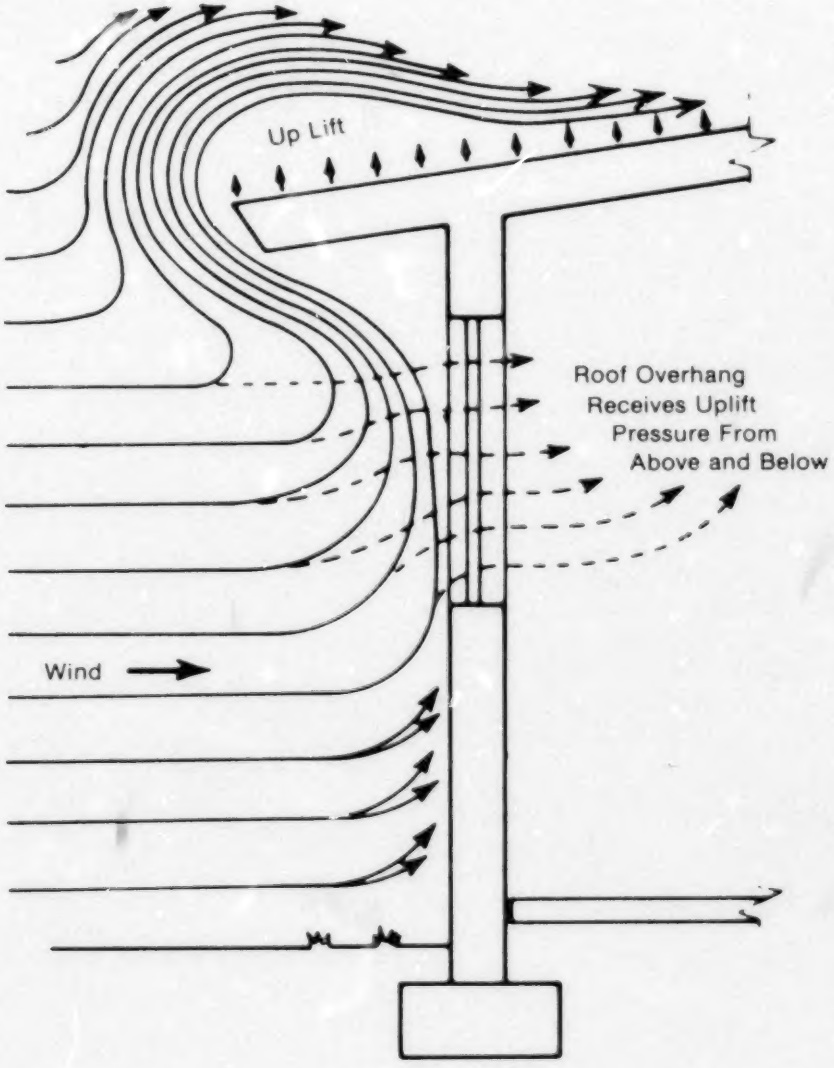

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John F. Kennedy High School

The Hazard—Earthquakes
The School—J.F. Kennedy, Sacramento, California.
The Architect—Stafford and Peckinpaugh

About the School:

John F. Kennedy High School, Sacramento, California is a comprehensive high school offering a well-rounded curriculum to 2,000 students and was constructed as an SCSD building.

The foundation of this building is a concrete pad that allows for support column movement. This was necessitated through construction on a fill area.

A unique alarm system allows any teacher to alert the main office in times of emergency. Each teacher carries a pencil-like device which enables her to contact a receiving system which indicates the trouble area through a lighted panel.

Grades	Pupil Capacity	Area
10-12	2,000	230,732

Construction Cost	Per Sq. Ft. Cost
$4,408,214	$19.10

Additional cost for inclusion of earthquake protection = 2% of contract cost.

Kennedy Floor Plan

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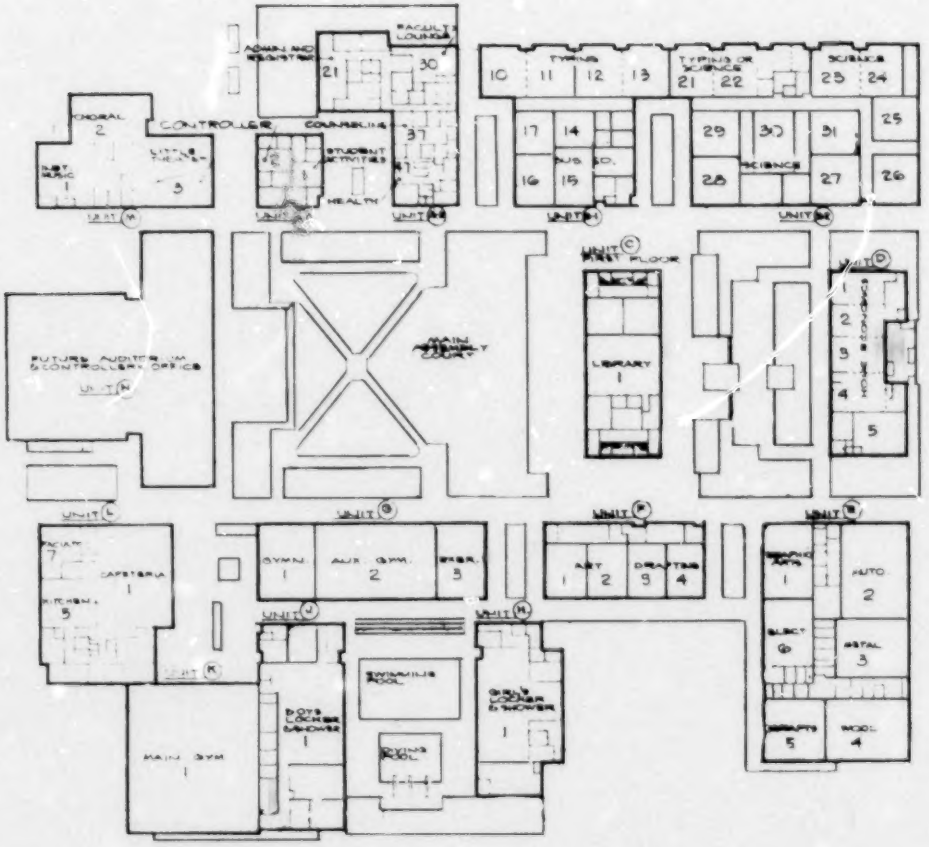
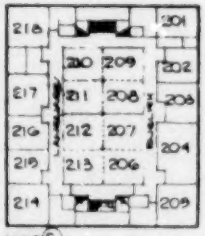
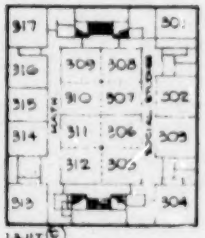




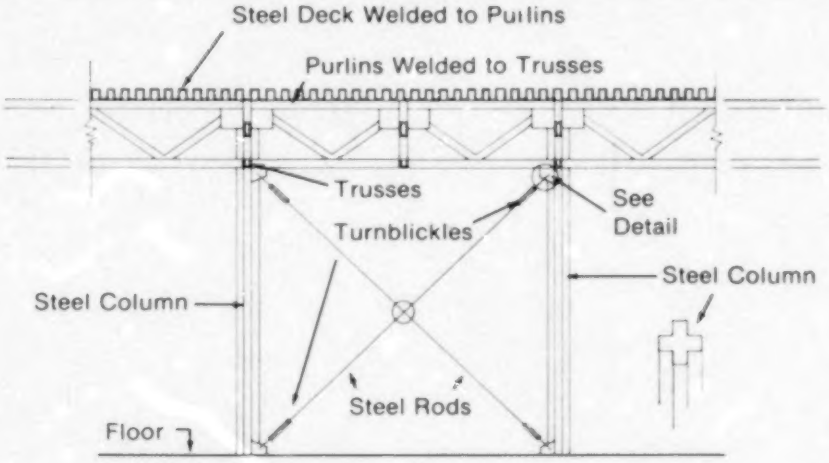


Construction Details

These drawings show a method of incorporating protection from seismic shock.

Steel rod bracing must be kept under tension by use of the turnbuckles. Uniformity in the location and length of shearing units throughout the entire structure makes the flow of forces smooth—results in economy as well.

Shearing units should be as symmetrical as possible so that torsion will not occur in the building.



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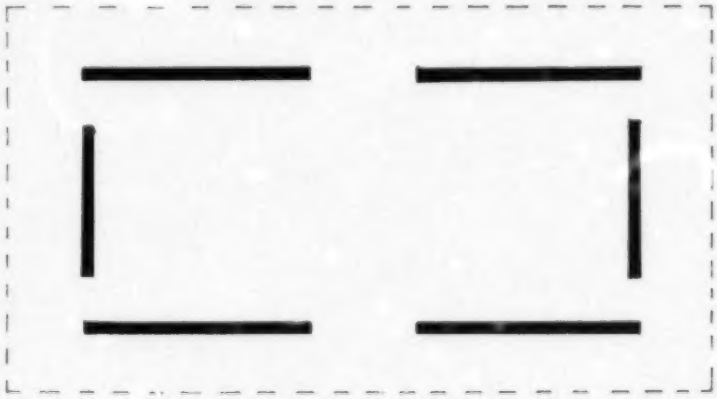
BALANCED SHEARING UNITS



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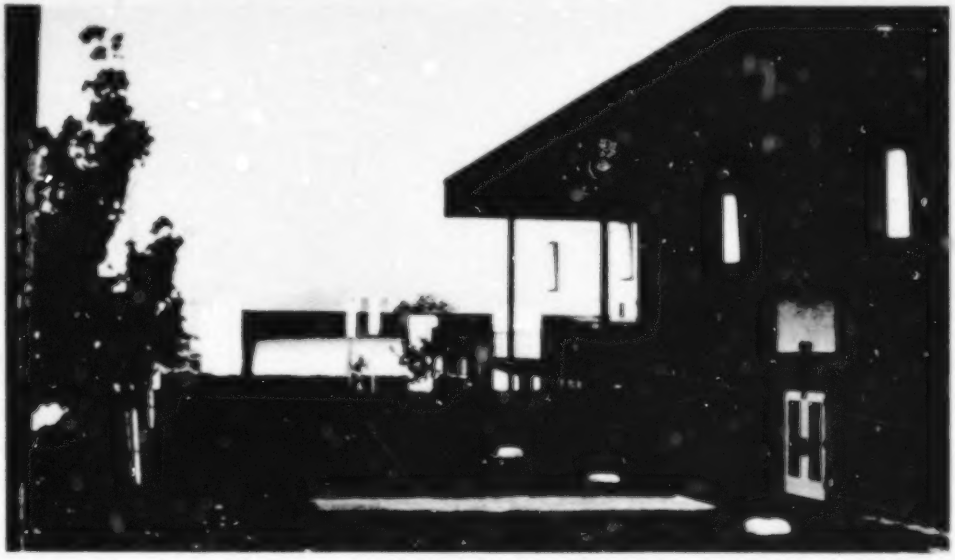

Oak Grove High School

The Hazard—Earthquakes
The School—Oak Grove High School, San Jose, California
The Architect—Alan Walters & Associates

About the School

Oak Grove High School is a four-year comprehensively designed facility located on 44 acres for 1850 students on a campus style plan. The campus consists of 16 individual buildings which house the various academic disciplines and supportive functions.

The structural subsystem is on a 5 foot by 5 foot horizontal and 2 foot vertical module and all subsystems must allow for interior design to be placed on a 4 inch by 4 inch module.

The interior allows for rearrangement of interior partitions with relocatable partitions and easily adaptable subsystems.

A unique feature of Oak Grove is the absence of a dining area. Food may be purchased from vending machines or from a school food preparation area. Students then dine in an open courtyard.

Incorporation of protection against seismic shock in SCSD buildings may be accomplished through moment resisting frames, shear walls, or a combination of both. The building configuration and its fundamental period affect its earthquake resistance considerably. Symmetry in plan aids in the elimination of high-stress-concentration areas.

Oak Grove Floor Plan

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